THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 2 – 2011, ISSN 1453 – 083X

THE INFLUENCE OF FRICTION FORCES IN METAL POWDERS COMPACTION PROCESS OF STAINLESS STEEL 316L

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ABSTRACT

The purpose of this study is to determine as precisely the influence of friction in the compaction of powders, and "conversion" of it, increasing densification.

The process is intended to be used in the compaction of hard deformable materials, which increased to approximately 90% densification required very high compaction pressures. These pressures are high, significant wear of the tools produce the compaction and thereby increasing production costs of finished parts from metal powders.

KEYWORDS: friction forces, "conversion", compaction, metal powder

1. Introduction

Technological processes that use pressure to achieve plastic deformation state are common element of friction forces. These forces can be active or resistive character depending on the context of their occurrence as: desirable or undesirable phenomenon in engineering.

Whatever the process of compaction, it involves a complex: factors, material and process variables. The ability to understand all the factors that influence individual particles are in a compact area of fundamental interest both for carrying out theoretical models and practical applications of these models. One of the factors specific to the compaction process is friction [2].

If for materials "full" (cast, forged, rolled), the force of friction depends on the type of contact (ie. a single type of contact throughout the deformation) and it causes one type of motion (sliding, rolling, the spin or the impact or combinations thereof), where powder densification of P/M can be no succession or simultaneously all types of motion caused by contact kinematics, during the process [3].

Types of friction in different stages of densification of powders are:

- Friction that occurs between two or more powder particles in contact between them, called static friction - friction contact (τ). It is given by the normal tension (σ_n) on the contact surface (Fig. 1) and coefficient of friction (μ).

- Friction that occurs when starting the pressing, the particles tumble while some others besides occupying vacancies - rolling friction (Fig. 1 b).

At this stage the powder particles are not deformed, the contact between them resumed at one point. As a result of the existence of gaps, because of its filling, the particles will move to these areas (least resistance) under the action of deformation tools.

Friction is in turn influenced by: the relative kinematics of contact, geometrical surface, the nature of the materials that form the coupling, the chemical composition of the body deformed and the deformation tool, the presence of impurities and a third coupling material, forming pressure (degree of deformation), deformation temperature, the relative speed of sliding contact surface.

Rolling friction is a complex phenomenon and is dependent on mechanical factors, physical and chemical. This type of friction can be classified:

- Rolling with high shear forces;

- Rolling with small tangential forces of friction is called "roll off".

- Friction that occurs at the start of deformation of particles, the elastic deformation - we call intermittent friction ("stick-slip") figure 1 c) [3, 4]. Particles have no where to move, can only rotate and deform (elastic deformation), thereby increasing the contact area between particles and between particles and walls tool.

- Friction that occurs between particles during the compaction effect, in which plastic deformation predominates.

At this stage the particles are in intimate contact (Fig. 1 d), so the entire surface of the particle is in contact with other particles or walls of the pressing tool. We call this type of friction sliding friction.

The same type of friction is found in contact with the walls of the powder forming tool at this stage of densification.

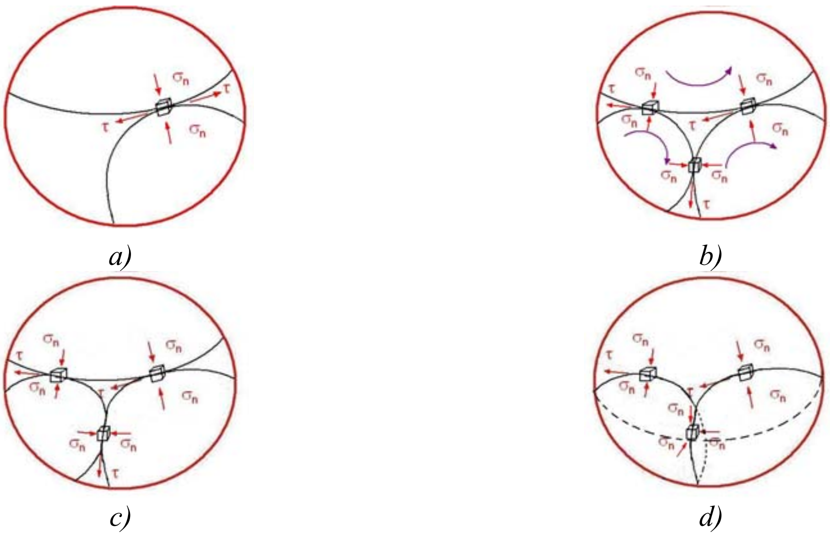


Fig. 1. *Powder compaction:*
a) powders are brought into contact by filling the die, b) early stage of deformation there is still pressing the powder particles, the particles stick to each other, spinning and tumbling vacancies c) compaction beginning: the emergence elastic strain at the contact between particles, d) effective compaction, material flow occurrence at the contact between particle and particle-surface tools.

- Ejection friction of green compacts process. This type of friction occurs between green compact and forming tools. In this phase may bring about a new compaction is the result of an improvement densification, or surface quality of green compacts. This friction is similar to the friction between blank and tools for solid materials.

The direction of this frictional force is the opposite movement of the material. Friction between particles of powders and between powder and tooling plays a major role during densification of PM parts. As a result there is a densification of green edges compacts.

2. Experimental procedure

Material. In this paper was used stainless steel powder 316L produced by gas atomization, with a particle size < 120 µm.

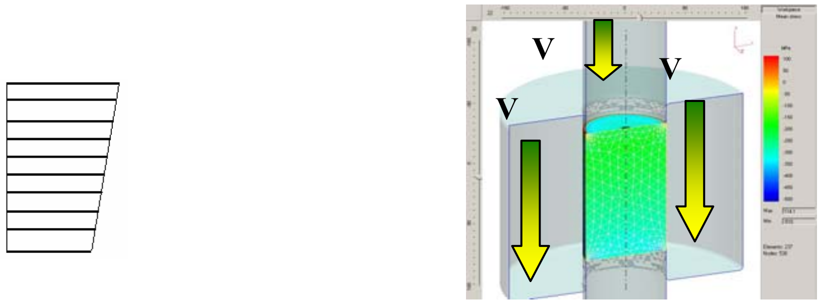
Cold compaction with assisted friction. Before compaction the powder was mixed with zinc stearate in a ratio of 0.5%.

Green compacts have been carried out on an tensile-compression test installation (Heckert) with maximum force of 200 kN, driven by a hydraulic cylinder located at the bottom.

The proposed process consists in moving the mold during the pressing, die movement in the same direction with a given speed (fig. 2). As a result, the frictional forces acting in the same direction as the punch achieving a better distribution of powder flow during compaction process.

Activation of friction [1, 5], plastic deformation processes, create a peripheral flow which causes the material in the central and peripheral axial-flow direction (deformation) (fig. 2,b)). Material from these two regions are moving simultaneously in the mold resulting in reduction of strains and increase their uniformity, strain, working speed and the degree of deformation. Thus, this procedure creates additional opportunities to reduce deformation due to flow uniformity and standardization of their right under certain conditions.

Sintering. Green compacts were sintered in a vacuum furnace room is equipped with an electric heater and temperature control, so they were maintained in vacuum (10-4 bar) at a temperature of 1200 °C for 60 minutes.



a) b)

Fig. 2. *Friction assisted compaction of 316L stainless steel powder*
a) density distribution, b) compaction process $V_m > V_p$

3. Results and discussion

Cylindrical green compacts were made of 6.5 grams and 10.5 grams with classical friction assisted compaction at a pressure of 600 MPa and 700 MPa. The inner diameter of the die is 11.12 mm, compacts obtained with varying heights depending on the weight, pressure and compaction process.

Table 1. *Densities obtained in the process of compaction*

No	Compaction process	Pressure [MPa]	Weight [gr]	Green density [gr/cm^3]	Density [gr/cm^3]
1	with assisted friction	600	10.5	6.29	6.49
2		700		6.50	6.67
3	classical	600		6.60	6.76
4		700		6.76	6.92
5	with assisted friction	600	6.5	6.45	6.61
6		700		6.60	6.69
7	classical	600		6.60	6.79
8		700		6.76	6.97

Densities were obtained after sintering fig. 3 between 82% and 89%, in line with the literature [4] (to 1240°C value obtained is 90% of theoretical density), taking into account the conditions of sintering.

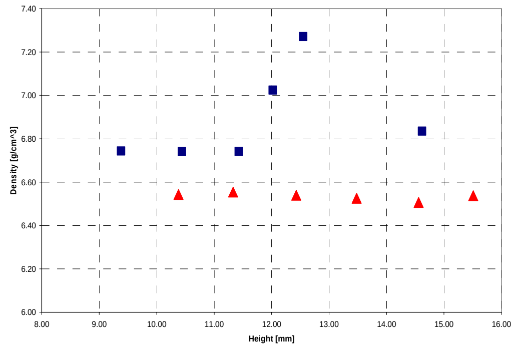
Density gradient was determined by removing the turning of 1 millimeter of material in radial section. Height density distribution reported in parts was determined by Archimedes method. Comparison of density gradient was performed for both processes at different compaction pressures (600 MPa and 700 MPa).

As can be seen, in fig. 3 a) and c) we obtained a uniform density distribution for samples of 10.5 grams with assisted compaction achieved by friction, but with lower values 1% ÷3% for samples compacted classic. The results obtained on samples of 6.5 grams comply with the trend to uniform density, which leads to the conclusion that the activation of friction produces densities with 1% ÷ 3% lower, but earn more by getting a better gradient. As a consequence, the fill height of the die is no longer conditioned to 3x height of compact. These results are applicable for parts with large lengths.

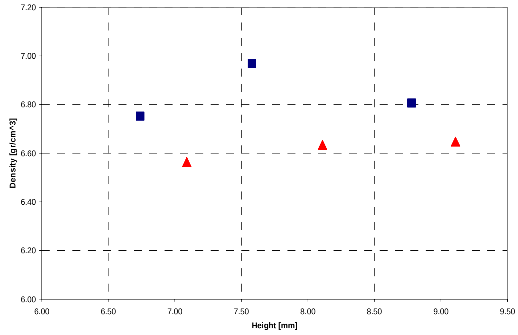
In what follows (fig. 4) presents microstructures in the process of sintering compacts in a vacuum. Metallographic samples were prepared as follows: longitudinal were polished with abrasive paper of 500-1200 grit, then polished with alumina and were etched with royal water (HCl 33%, 66% HNO_3).

It is noted that the material was sintered well. The resulting structure is similar to a molten metal, is observed grains (crystallites - white areas) with polygonal boundaries clearly outlined. The microstructures presented for both classical and assisted compaction processes are very similar. In both, approaches can be distinguished macles in specific grain austenitic steels and fine carbides (small black dots on grains), due to alloying elements, the basic blend of grain weight.

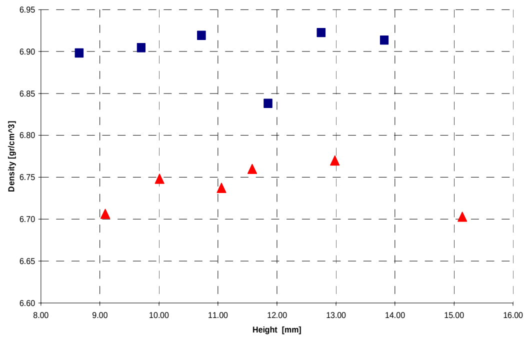
10.5 gr *6.5 gr*



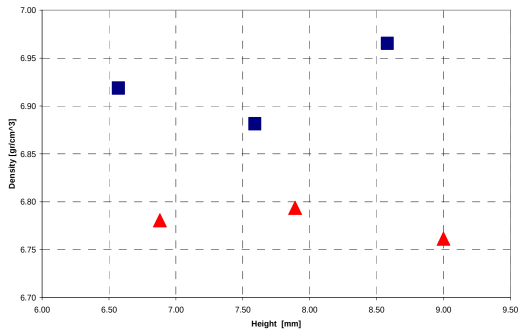
a)



b)



c)

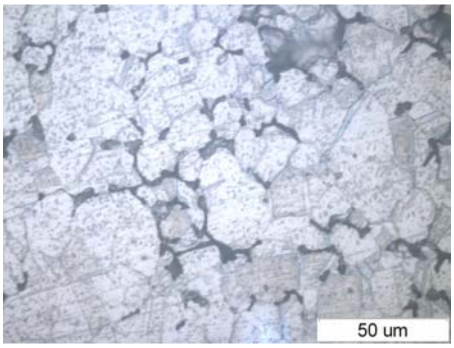


d)

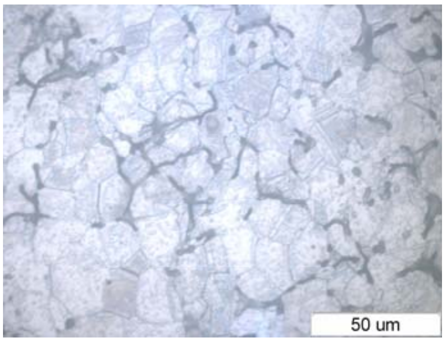
■ *classical compaction* ▲ *friction assisted compaction*

Fig. 3. *Density gradient of stainless steel powder, 316L*
a), b) pressure at 600 MPa; c), d) pressure at 700 MPa.

So, if compact 6.5 grams, fig. 4, 5 a), b) and for those of 10.5 grams, fig. 4, 5 c), d), we see a greater number of grains in the microstructures obtained at compaction with friction assisted fig. 4 b), d). This is due to the presence of friction assisted, given that the same conditions were observed in compaction.



a)



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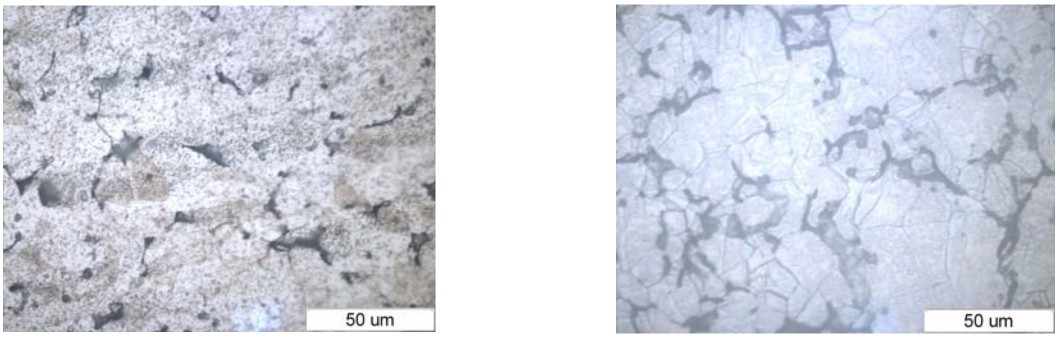


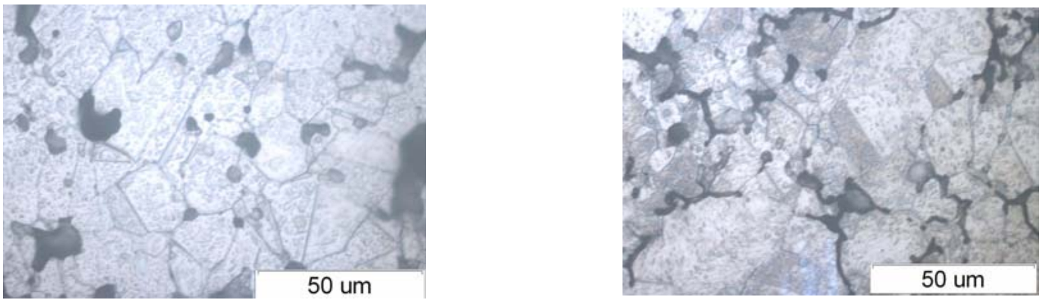
c) *d)*

Fig. 4. *Microstructures of 316L stainless steel samples compacted at pressure of 600 MPa: a) classical compaction of 6.5 g samples, b) with friction assisted compaction of 6.5 g samples, c) classic compaction samples of 10.5 g d) compaction with friction assisted samples 10.5 gr.*

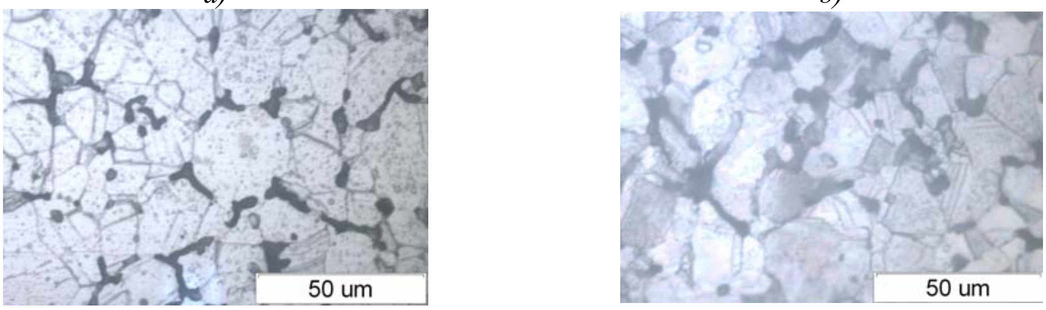
It can be seen in the microstructure, the presence of an amount of pores (dark areas), this fact it is specific sintered structures. Porosity decreases according to the method of compaction, compaction pressure and sintering temperature.

The explanation for the existence of an increased amount of pores, or pore size may result from the dependence of compaction speed. A too rapid compaction (low height for samples) can be achieved without the grain to find the most advantageous positions of green compact volume.

The boundaries between grains are well defined and can be seen present carbides in the grain.



a) *b)*



c) *d)*

Fig. 5. *Microstructures of 316L stainless steel samples compacted at pressure of 700 MPa: a) classical compaction of 6.5 g samples, b) with friction assisted compaction of 6.5 g samples; c) classical compactness samples of 10.5 g d) compaction with friction assisted samples of 10.5 grams.*

Conclusions

It was comparatively studied in this paper, two methods of densification of powders, classic - bilaterally and with friction assisted. Differences between classical and assisted friction compaction is relatively low, due to the small size of samples. The compact with longer lengths could be more relevant results.

The main difference between the two processes is given by the influence of frictional forces between particles, powders and tools.

Advantages:

- uniform density distribution of the green compact height
- removal of the neutral zone
- low density in the case of the classical-bilateral compaction
- unconditional height filling of compact height
- activation of friction between the container and the powder effecting in the reduction of the pressing force applied to the die
- minimum implementation costs in industry, concerning only the movement of the mobile device for driving the mold
- long time suitability of friction assisted compaction for resistive deformable materials.

Disadvantages:

- compact density reduction by 1% ÷ 3%
- implementation costs of the appropriate process
- location of the training devices on the existing press.

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